

# **COST AND PERFORMANCE REPORT**

**Thermo NUtech's Segmented Gate System**

**Idaho National Engineering and  
Environmental Laboratory  
Auxiliary Reactor Area-23**

**Idaho Falls, Idaho**

**Accelerated Site  
Technology Deployment**

**U.S. Department of Energy**

**November 1999**

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## **LIST OF ACRONYMS**

ARA	Auxiliary Reactor Area
ASTD	Accelerated Site Technology Deployment Program
CEARP	Comprehensive Environmental Assessment and Response Program
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
DOE	Department of Energy
DOE-ID	U.S. Department of Energy Idaho Operations Office
EPA	Environmental Protection Agency
ER	Environmental Restoration
ES&H	Environment, Safety and Health
FFA/CO	Federal Facility Agreement and Consent Order
GPRS	Global Positioning Radiometric Scanner
HSWA	Hazardous and Solid Waste Amendments
INEEL	Idaho National Engineering and Environmental Laboratory
ITRD	Innovative Treatment Remediation Demonstration
PPE	Personal Protective Equipment
PRG	Preliminary Remediation Goal
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
ROD	Record of Decision
SGS	Segmented Gate System
SL	Stationary Low-Power Reactor
SVOC	Semi-volatile Organic Compound
SWMU	Solid Waste Management Unit
TRU	Transuranic Radionuclides
WBS	Work Breakdown Structure

## FOREWORD

The Department of Energy (DOE) is working to accelerate the acceptance and application of innovative technologies that improve the way the nation manages its environmental remediation problems. The DOE Office of Science and Technology established the Accelerated Site Technology Deployment Program (ASTD) to help accelerate the acceptance and implementation of new and innovative soil and ground water remediation technologies. Coordinated by the Department of Energy's Idaho Office, the ASTD Program reduces many of the classic barriers to the deployment of new technologies by involving government, industry, and regulatory agencies in the assessment, implementation, and validation of innovative technologies.

Funding is provided through the ASTD Program to assist participating site managers in implementing innovative technologies. The program provides technical assistance to the participating DOE sites by coordinating DOE, industry, and regulatory participation in each project; providing funds for optimizing full-scale operating parameters; coordinating technology performance monitoring; and by developing cost and performance reports on the technology applications.

In 1995, the DOE's Innovative Treatment Remediation Demonstration (ITRD) Program initiated a joint project with DOE Plants in Ohio to investigate the use of innovative technologies for the remediation of heavy-metal contaminated soils. Preliminary technology assessments indicated that processing radionuclide-contaminated soils through physical separation using advanced sensors was cost-effective and could significantly reduce the volume of soil requiring either further treatment or off-site disposal. The ITRD program sponsored a study using the Segmented Gate System (SGS) for separating uranium and plutonium contaminated soil from clean soil. Based on these results, Sandia National Laboratories' Environmental Restoration Project and the ITRD Program sponsored a soil remediation effort at Sandia's Technical Area II in August and September 1997 using the SGS. The system was used to cost effectively separate clean and contaminated soil for four different contaminants; plutonium, uranium, thorium, and cesium. Based on those results, the DOE's Ohio Field Office submitted an ASTD proposal to use the SGS at seven other DOE sites across the country.

The purpose of this Cost and Performance Report is to document the project activities, project data, and provide evaluation results of the operational cost and performance of the ASTD deployment of the SGS at the Idaho National Engineering and Environmental Laboratory (INEEL), Auxiliary Reactor Area -23(ARA-23), soil remediation site.

## 1. SUMMARY

Thermo NUtech conducted a volume reduction project on radiologically contaminated soil for the Idaho National Engineering and Environmental Laboratory (INEEL) at Auxiliary Reactor Area-23 (ARA-23). ARA-23 is a 41.8-acre site containing windblown contamination. Most of the contamination came from cleanup of the accidental destruction of the SL-1 reactor in 1961. The contaminant of concern is Cesium-137. The preliminary remediation goal for this site was established at 23 pCi/g, which represents future residential development.

The INEEL is an 890-square mile facility operated by the U.S. Department of Energy. It is on the eastern Snake River Plain, a relatively flat, semiarid desert in southeastern Idaho (Figure 1). Drainage within and around the plain recharges the Snake River Plain Aquifer. The aquifer provides groundwater for irrigation and drinking water throughout the Snake River Plain. The ARA was constructed in the late 1950s to support the Army Nuclear Program. It has four separate operational areas and facilities that have not been used since the 1980s and are currently in varying stages of decontamination and dismantling. Because of confirmed contaminant releases to the environment, the INEEL was placed on the National Priorities List of hazardous waste sites in 1989. Agencies signed the Federal Facility Agreement and Consent Order in 1991 outlining the cleanup process and schedule for the INEEL.

The Thermo NUtech Segmented Gate System (SGS) was mobilized to ARA-23 site on June 1, 1999, to an area that had been previously prepared by LMITCO personnel. INEEL contractors provided crane support for equipment off-loading during mobilization, all heavy equipment support throughout the deployment and crane support for the demobilization. Assembly and calibration were accomplished over a five-day period. Soil processing began on Wednesday, June 10<sup>th</sup> and ended on June 30<sup>th</sup>, 1999. The goal of the project was to reduce the volume of contaminated soil that would require off-site disposal. The scope of work for the SGS deployment called for processing 1,000 yd<sup>3</sup>. Only 442 yd<sup>3</sup> were processed because the expected results were not being achieved and prior arrangements had not been made for disposal of more than 30% waste.

An estimated total of 1,040 yd<sup>3</sup> of soils were excavated and stockpiled from two areas within ARA-23, representing sediment (spill) and windblown type contaminant depositions, respectively. 442 yd<sup>3</sup> of the stockpiled soil was processed, with an overall volume reduction of less than 3%. Although the desired volume reduction of 90% was not met, several lessons were learned during the soil processing that can be applied to future deployments of the segmented gate system technology.

## 2. SITE INFORMATION

### Identifying Information

*Facility:* Idaho National Engineering and Environmental Laboratory  
*Location:* Idaho Falls, Idaho  
*OU/SWMU:* Auxiliary Reactor Area-23  
*Regulatory Driver:* CERCLA  
*Type of Action:* Corrective Measure – Site Remediation  
*Technology:* Thermo NUtech's Segmented Gate System  
*Period of operation:* June 1st 1999, to June 30<sup>th</sup>, 1999  
*Processed volume:* 442 yd<sup>3</sup>

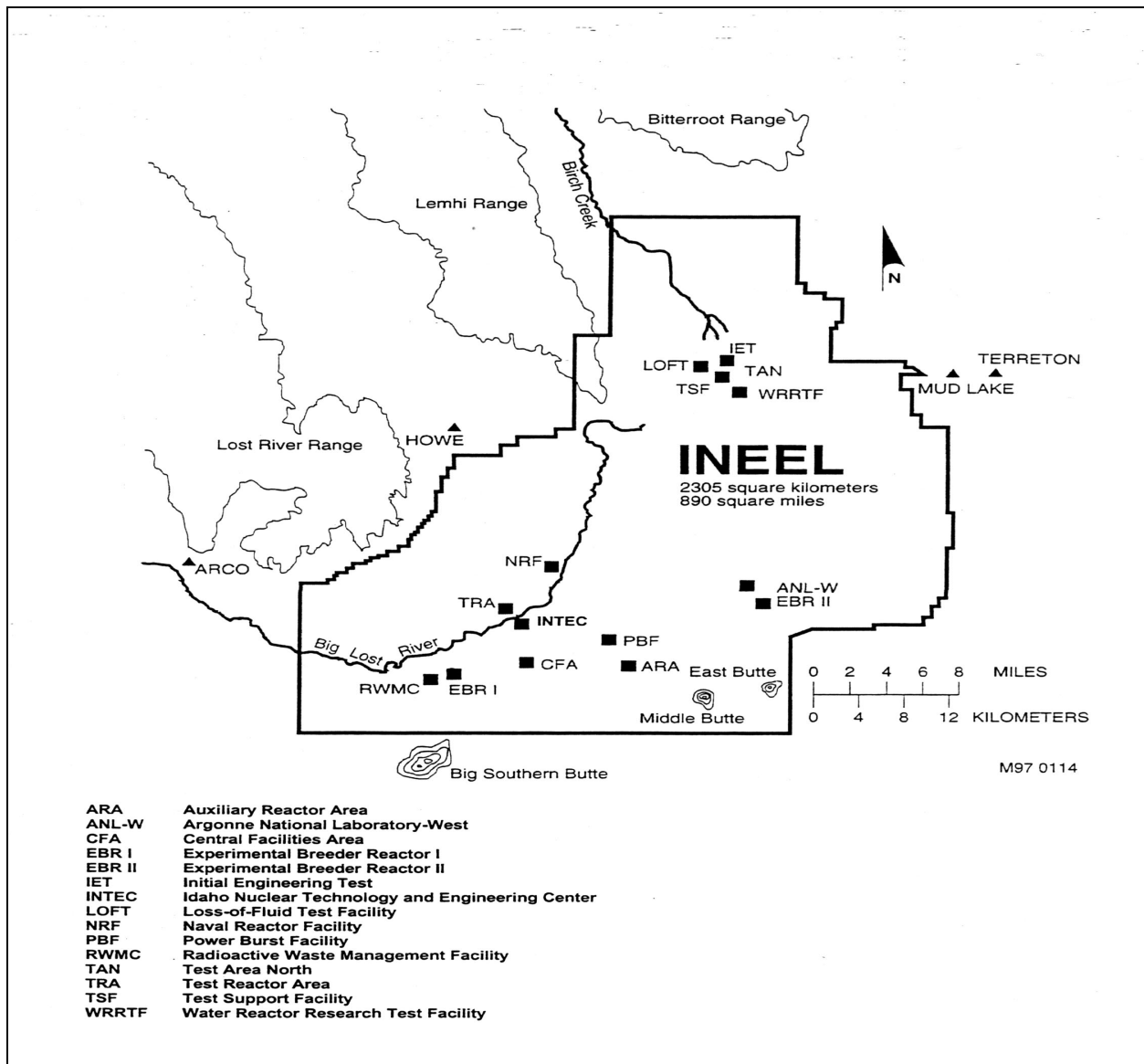


Figure 1. INEEL Location Map

## **Site Background**

The INEEL, formerly the National Reactor Testing Station encompasses 890 mi<sup>2</sup>, and is located 34 miles west of Idaho Falls, Idaho (Fig. 1). The United States Atomic Energy Commission, now the Department of Energy, established the Idaho National Engineering Laboratory, now the Idaho National Engineering and Environmental Laboratory, in 1949 as a site for building and testing a variety of nuclear facilities. The INEEL has also been the storage facility for transuranic (TRU) radionuclides and low-level radioactive waste since 1952. INEEL supports the engineering and operations efforts of DOE and other federal agencies in the areas of nuclear safety research, reactor development, reactor operations and training, nuclear defense materials production, waste management technology, energy technology and conservation programs. The DOE-Idaho Field Office has responsibility and authority to operate the INEEL. The ARA-23 site is a large, roughly oval-shaped windblown contamination site encompassing the SL-1 Burial Ground and the remnants of the ARA-I and ARA-II facilities. The site was originally defined as the subsurface structures (e.g., reactor building foundation and underground utilities), soil contamination within the ARA-I and ARA-II facility fences, and all radiologically contaminated surface soils surrounding the ARA-I and ARA-II facilities as defined by an aerial survey isopleth. The long axis of the site is consistent with the generally southwest to southeast winds common on the INEEL. Soils were radiologically contaminated by the 1961 SL-1 accident and subsequent cleanup. Minor amounts of contamination may have been added by other ARA operations.

## **Release Characteristics**

The soil from ARA-23 that was used in the Treatability Study came from two areas: (1) where the SL-1 equipment was decontaminated and (2) an adjacent area consisting of windblown contamination. The approximate combined processed volume was 442yds<sup>3</sup>. The two areas are considered to be a result of different depositional modes; therefore, the soils were treated separately. The SL-1 decontamination area is considered a sediment depositional type soil, and the other areas of ARA-23 as windblown. The GPRS data collected for ARA-23 showed significant spread of Cs-137 contamination, much of it exceeding 45 pCi/g.

## **Site Contacts**

Funding for the project was provided under the Accelerated Site Technology Deployment Initiative under the direction of Ray Patteson, of Sandia National Laboratories [(505) 844-1904]. The technical contact for the INEEL SGS treatability study is Frank Webber, of INEEL [(208) 526-8507]. The project manager for Thermo NUtech is Joe Kimbrell in Albuquerque, NM [(505) 254-0935 ext. 209].

### 3. MATRIX AND CONTAMINANT DESCRIPTION

The type of matrix treated by the SGS at INEEL ARA-23 was radionuclide-contaminated surface soil to a depth of three inches mixed with clumps of grass and no significant debris or oversized material.

#### ***Site Geology / Hydrology***

The surface of the INEEL is covered by Pleistocene and Holocene basalt flows ranging in age from 300,000 to 3 million years. These basalts erupted mainly from northwest-trending volcanic rift zones, marked by belts of elongated shield volcanoes and small pyroclastic cones, fissure-fed lava flows and non-eruptive fissures or small displacement faults. A prominent geologic feature of the INEEL is the flood plain of the Big Lost River. Alluvial sediments from the Quaternary age extend across the INEEL from southwest to northeast. In the site's northern portion the Big Lost River enters a series of playa lakes. In the southern portion three large silicic domes (the East, Middle, and Big Southern buttes) are prominent landmarks.

Surface hydrology at the INEEL includes water from three streams that flow intermittently onto the INEEL and from local runoff caused by precipitation and melting snow. Most of the INEEL is located in the Pioneer Basin into which three streams drain: the Big Lost River, Lost Little River and Birch Creek. These streams receive water from mountain watersheds located to the north and northwest. Stream flows are often depleted before reaching the INEEL by irrigation diversions and infiltration losses along stream channels. The Pioneer Basin has no outlet; therefore, when water flows onto the INEEL, it typically evaporates or infiltrates into the ground.

#### ***Nature and Extent of Contamination***

The only contaminant of concern found in the characterization of ARA-23 was Cs-137. The GPRS data collected for ARA-23 showed significant spread of Cs-137 contamination, much of it exceeding 45 pCi/g. The Cs-137 contamination is estimated to affect fifty thousand cubic yards of soil to depths of only three inches.

#### ***Matrix Characteristics Affecting Treatment Cost or Performance***

The ARA-23 site soils are typical of the southern area and are generally shallow, consisting of fine-grained eolian soil deposits with some fluvial gravel and gravelly sands. Data from well logs indicate average surface sediment thickness of 1.5 feet in the ARA portion of the INEEL.

Thermo NUtech did not perform any sieve analysis on the soils to be treated at ARA-23. The soil treated was removed from the top three inches and placed into windrows to be picked up and deposited into stockpiles for subsequent loading into the hopper of the SGS. The excavated soil presented a challenge to the SGS processing. The soil is typical rangeland and contains clumps of grass. The root system and grass stems of these clumps and excessive soil moisture content caused the grizzly to clog and the hopper to overflow.

## 4. TECHNOLOGY DESCRIPTION

### *Purpose of Technology*

Due to depositional mechanisms, contaminated soil is often heterogeneously distributed. The SGS is used to separate radionuclide contaminated soil from clean soil. The goal is to separate the contaminated soil to a predetermined acceptable level, reduce the volume of contaminated soil requiring disposal and reduce soil disposal costs.

### *Segmented Gate System Description*

The Thermo NUtech SGS is a transportable gamma radiation detector system with motorized conveyor belts, a variable belt speed motor controller, air actuated segmented gates, a radionuclide assay computer system, and two arrays of sodium iodide (NaI) detectors applicable to radionuclides that emit low and high energy gamma rays. This mobile unit includes a material feed conveyor, a sorting conveyor coupled to a sophisticated motor control unit to assure constant belt speed, a contaminated material conveyor, and a below criteria material conveyor.

The sorting conveyor, detector arrays, segmented gates, and all downstream conveyors and subsystems are controlled through the use of an on-board computer that is operated from a mobile van. The computer makes soil-processing decisions based on operating parameters entered by the control room technician. The operating display on the computer shows real-time status of the conveyor monitor system and will automatically shut down all components when abnormal conditions are detected.

In addition to the components of the sorting system itself, several support components are needed for operation of the system. A transportable air compressor provides air pressure for the pneumatic cylinders. A separate van houses the computer and also provides operating space for the control room technician. A portable generator may be used if commercial power is not available. The equipment weighs 40,000 lbs. so a 35 to 50 ton crane is needed for loading and unloading equipment in addition to a forklift. A front-end loader with a 2 to 5 yard bucket no greater than 8.5' in width is needed to move soil to and from the SGS plant. Site requirements for SGS staging and soil processing are listed in Table 1.

**Table 1. SGS Staging and Area Processing Requirements**

Provision	Requirement
Staging Area	Level area, 100 feet x 130 feet
Power	250A, 208V, 3 phase 115V power for overnight and weekend detector temperature control
Water	Water supply for dust suppression (100 to 200 gallons per day)
Ancillary Equipment	35 to 50 ton crane, loader with 2 to 5 yard bucket no wider than 8.5', fork lift

## **Technology Advantages**

The processing of radionuclide-contaminated soils using the SGS offers the following advantages:

- The system physically surveys the entire volume of soil to be processed,
- The system typically reduces volumes of soil needing treatment or disposal,
- No chemicals or other additives are used,
- The generation of secondary waste is typically limited to PPE,
- Dry decontamination of the SGS has proven effective and
- Hydraulic system contains BioSoy®, an environmentally friendly soy bean based hydraulic fluid replacement

## **Technology Limitations**

The SGS has the following limitations:

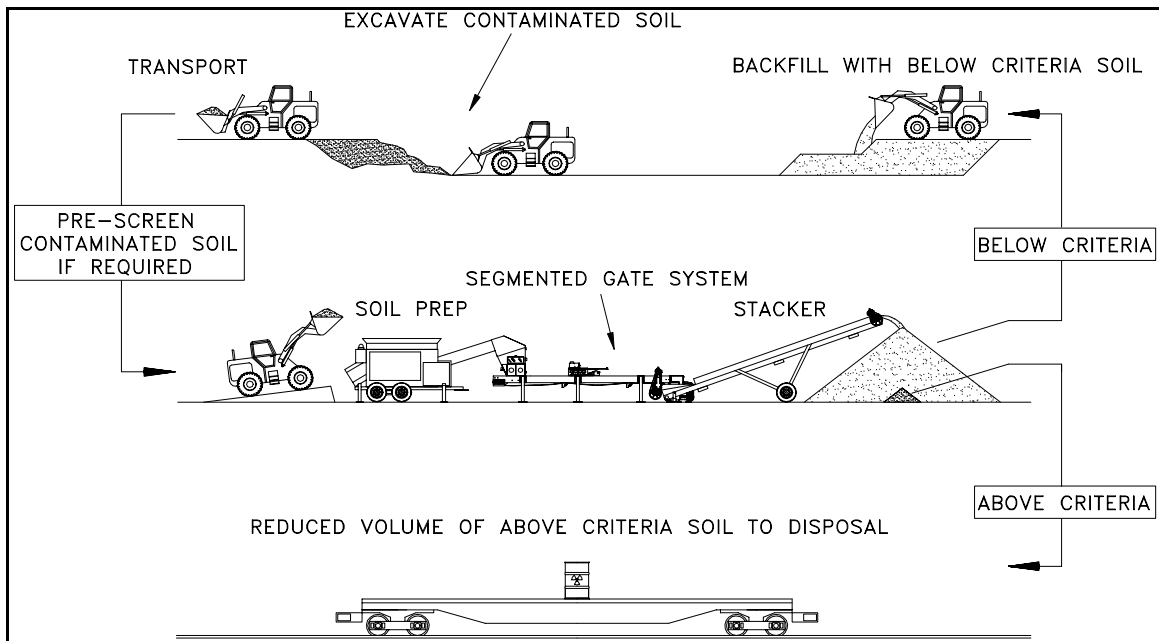
- The two detector arrays provide the ability to analyze a maximum of two radionuclides at a time with different gamma energies,
- The SGS is primarily limited to gamma emitting radionuclides, although it can be modified to detect beta particle emitting radionuclides,
- Prior knowledge of the primary radioactive contaminants is required and soil cannot be properly sorted for unknown radioactive contaminants,
- Soil may contain levels of radioactivity above the criteria if it is sorted based on the wrong radionuclides, and
- Material greater than 1-2 inches in diameter cannot be processed by the SGS without pre-crushing.

## **Processing System Schematic and Operation**

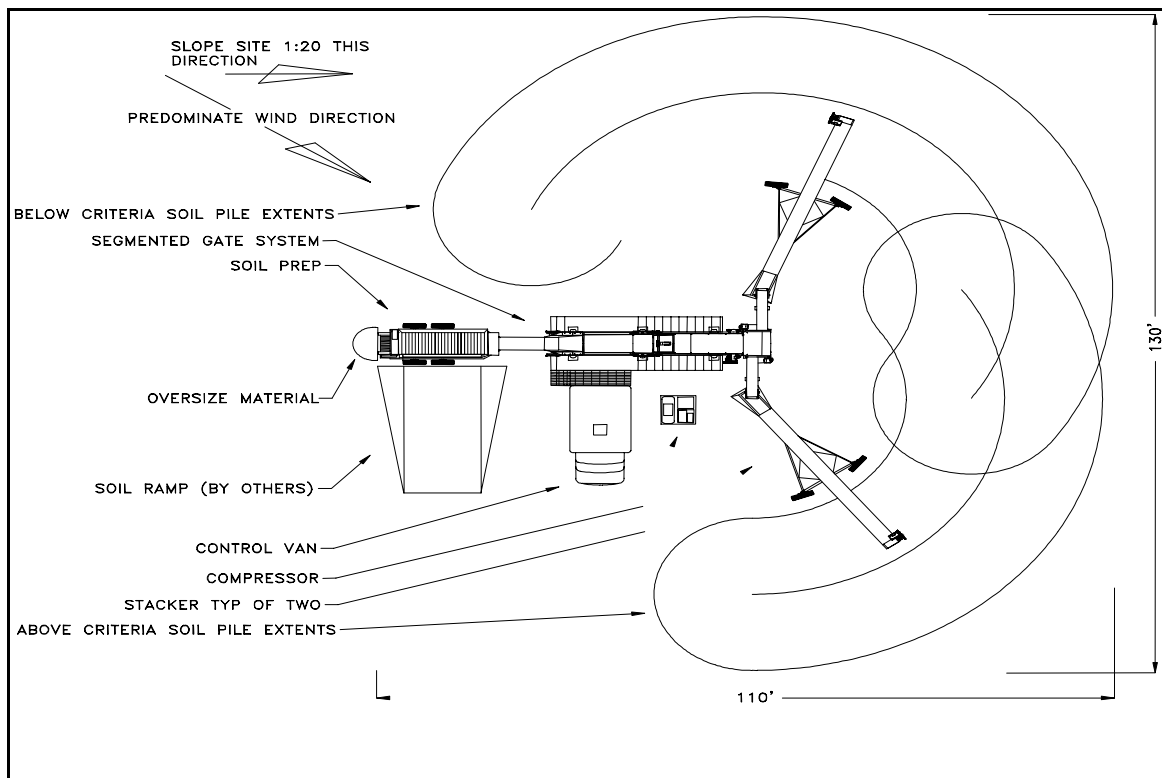
Figure 1 shows the process flow of the SGS under typical operating conditions. During system operation, contaminated soil is excavated with standard heavy equipment and relocated to the feed point of the mobile SGS processing plant. The soil is first pre-sorted into piles using a vertical bar field grizzly, which removes material larger than 6 inches in diameter. The soil is then sent through the SGS screen and hammer mill, and all rocks and debris greater than 1 to 2 inches in diameter are removed. The remaining soil is deposited in the feed surge bin. The surge bin deposits soil on the SGS conveyor belt using a screed to control the thickness and width of the soil layer. The SGS screed is adjusted to spread the material across the conveyor belt to a depth appropriate for the radioisotope of interest and the soil characteristics. The soil passes under two sets of gamma radiation detector arrays housed in shielded enclosures. The first, the thin array, is designed for 0.16 inch-thick sodium iodide (NaI) detectors, which are generally used to detect gamma radiation from 15 keV to 200 keV. The second, the thick array, is designed for 2 inch-thick NaI detectors, which are generally used to detect gamma radiation from 150 keV to 1 MeV. Either set of NaI detectors may be replaced by a beta detector system that uses 100 cm<sup>2</sup> gas proportional detectors. These detectors may be used to monitor beta-emitting radionuclides in the top 0.25 inches of the soil layer on the conveyor belt. This measurement may then be used to infer the beta emitting contamination in the remaining thickness of the soil layer on the conveyor belt.

The process material is conveyed underneath the detector arrays at a pre-selected speed, based on the separation criteria, contaminant, and soil type. The arrays are linked to a control computer, which toggles pneumatic diversion gates located at the end of the sorting conveyor. Contaminated material that exceeds the separation criteria for radioactivity is diverted to the contaminated material conveyor, where it is transferred to a stacking conveyor on one side of the SGS. The below criteria material falls onto the below criteria conveyor that transports it to a second stacking conveyor on the opposite side of the SGS.

The footprint requirements for the SGS are shown in Figure 3.



**Figure 2. Segmented Gate System Process Flow Diagram**



**Figure 3. Segmented Gate System Footprint**

## **Key Design Criteria**

The application and utility of the SGS is affected by several site-specific factors. The primary factors are the gamma energies of the radioactive isotopes of interest, the attenuation of the soil for the energies of interest, and the density of the soil. Depending on these factors, soil may be processed in layers varying between 0.5 and 2.0 inches thick. The SGS is capable of operating at belt speeds between 20 and 40 feet per minute. The belt speed selection depends upon the sensitivity of the radiation detectors to the radioisotope of interest, the background levels, and the volume processing requirements. Minimum belt speeds allow each fraction of the soil to be counted for a longer time, increasing the sensitivity by collecting an increased number of counts for the same volume of soil. If the sensitivity is sufficient, the belt speed can be increased to enhance production levels. This results in a minimum throughput of 8.5 yd<sup>3</sup>/hr and a maximum throughput of 28.5 yd<sup>3</sup>/hr per sorting conveyor assuming a nominal soil density of 1.2 g/cm<sup>3</sup>. Since the detector arrays can be operated simultaneously, the SGS can monitor a second radioactive contaminant while looking for the primary radionuclide of concern. A separate calibration is required for each contaminant.

## **Operating Parameters**

The operating parameters for the SGS at ARA-23 were selected to provide the optimum sensitivity for the contaminant of interest, cesium-137. The belt speed and soil layer thickness were chosen to maximize production for the sensitivity required to achieve the client specified criteria, which were developed using risk-based calculations for the anticipated future use of the site. The thin detector array was not used and was replaced with gas proportional beta detectors in monitoring mode. The original operating parameters and detector settings are summarized in Table 2 below. Once production sorting was stopped by the client processing changed to an R&D mode. Parameters and settings were changed for each test and are outlined, along with the results, in tables 5 through 9.

**Table 2. Operating Parameters Affecting Treatment Costs or Performance**

Parameter	Value or Specification
Processing speed	30 fpm (sorting conveyor belt speed)
Belt length from detectors to conveyor end	Thin array: 16.0 ft (4.88 m) Thick array: 18.0 ft (5.5 m)
Soil layer thickness	2 inches (5.08 cm)
Soil layer width	30.75 inches (78.1 cm)
Soil density (on the conveyor belt)	0.95 g/cm <sup>3</sup> , See Table 3
Detector type	Sodium iodide (NaI) 2 x 2 inch thick crystal

**Table 2a. SGS detector settings at ARA-23**

Contaminant	Detector Array	Gamma Energy Region of Interest	Distributed Alarm Setpoint	Multiple Particle Factor
Cesium	Thick	546-776 keV	23 pCi/g	3 (69 pCi/g)

## 5. SEGMENTED GATE SYSTEM PERFORMANCE

### *SGS Operational Capability*

The overall impression was that SGS operated as expected and had good reliability but that some equipment modifications should be made for future deployments. These modifications are listed in Section 9. Mobilization, system setup and calibration were accomplished during the allotted time. There were some operational delays due to grass clumps in the soil to be treated. Demobilization went as expected and there were no problems decontaminating the SGS equipment prior to it leaving the site.

### *Project Objectives and Approach*

The primary objectives of the INEEL ARA-23 SGS ASTD project were:

- Assess various operational parameters and determine their influence on:
- The volume of soil requiring off-site disposal
- The volume of Cs-137 that could be removed cost-effectively and
- The expected impact on overall remediation costs using the SGS.

### *Performance Summary*

Soil excavation and stockpiling of soils from ARA-23 Area A (sediment deposition area) and Area C (windblown deposition) began on May 20, 1999. Stockpiling operations were completed June 9, 1999. The areas were re-surveyed using the GPRS to evaluate the efficiency of the excavation procedures at removing the contaminated soil, and to further evaluate the extent of contamination remaining in the excavated areas. Table 3 summarizes the estimated amounts of soils stockpiled and processed during this treatability study.

**Table 3. SGS Treatability Study, Soils Stockpiled and Processed.**

New Soil Processed	Reprocessed Soil	
ARA-23 Area A. Estimated Soil Stockpiled—116 m <sup>3</sup> (152 yd <sup>3</sup> )		
Day 1—22 m <sup>3</sup> (28 yd <sup>3</sup> )	Day 6—8 m <sup>3</sup> (10 yd <sup>3</sup> )	
Day 2—65 m <sup>3</sup> (85 yd <sup>3</sup> )		
Total—87 m <sup>3</sup> (113 yd <sup>3</sup> )	Total—8 m <sup>3</sup> (11 yd <sup>3</sup> )	Area A Total—95 m <sup>3</sup> (124 yd <sup>3</sup> )
ARA-23 Area C. Estimated Soil Stockpiled—679 m <sup>3</sup> (888 yd <sup>3</sup> )		
Day 3—45 m <sup>3</sup> (59 yd <sup>3</sup> )	Day 4—6 m <sup>3</sup> (7 yd <sup>3</sup> )	
Day 4—28 m <sup>3</sup> (37 yd <sup>3</sup> )	Day 5—9 m <sup>3</sup> (12 yd <sup>3</sup> )	
Day 5—43 m <sup>3</sup> (56 yd <sup>3</sup> )	Day 7—17 m <sup>3</sup> (23 yd <sup>3</sup> )	
Day 6—19 m <sup>3</sup> (25 yd <sup>3</sup> )		
Total—135 m <sup>3</sup> (177 yd <sup>3</sup> )	Total—32 m <sup>3</sup> (42 yd <sup>3</sup> )	Area C Total—167 m <sup>3</sup> (219 yd <sup>3</sup> )
ARA-23 Total Soils Processed, Excluding Oversized Materials – 262 m <sup>3</sup> (343 yd <sup>3</sup> )		
Area A Oversized – 30 m <sup>3</sup> (39 yd <sup>3</sup> )*		
Area C Oversized – 46 m <sup>3</sup> (60 yd <sup>3</sup> )*		
ARA-23 Total Soils Processed, Including Oversized and Re-run – 338 m <sup>3</sup> (442 yd <sup>3</sup> )		
* Assuming oversize material at 25.5% of total volume.		

### **Area A Soils (Sediment Radionuclide Deposition)**

Area A soils were excavated first by using a grader to windrow the top 7.5 to 10.2 cm (3 to 4 in.) of soil. A front-end loader was used to pick up the soils and load them into dump trucks. After the excavated soil was removed from the area, the GPRS surveyed the area. The results of the initial and second survey show that a considerable amount of the activity above 23 pCi/g was removed during the excavation.

Table 4 shows that of the estimated 116 m<sup>3</sup> (152 yd<sup>3</sup>) of soil stockpiled, 113 yd<sup>3</sup> were processed with 97.3% of the soil (excluding oversized) exceeding the 23 pCi/g set-point for Cs-137. A conservative approach is to assume that the oversized material also exceeds the 23 pCi/g action level, unless sampling and analysis show otherwise. The low separation efficiency achieved for the ARA-23 Area A soils was assumed, and accepted, to be due to the homogeneity of the Cs-137 contamination in excess of 23 pCi/g. The homogeneous distribution of contamination was expected with spill or sediment type contaminant depositions, and confirmed with this test.

**Table 4. ARA-23 Area A soil summary.**

Estimated Soil Stockpiled	116 m <sup>3</sup> (152 yd <sup>3</sup> )
Total Soil Processed	87 m <sup>3</sup> (113 yd <sup>3</sup> ) <sup>*</sup>
Estimated Oversized Material	30 m <sup>3</sup> (39 yd <sup>3</sup> ) (25.5%)
Total Soil Diverted	84 m <sup>3</sup> (110 yd <sup>3</sup> )
Total Activity Diverted	3.94E+09 pCi (49.1 pCi/g, Average concentration)
Total Activity Not Diverted	2.28E+07 pCi (9.46 pCi/g, Average concentration)
Clean-up Efficiency	2.7%
Actual Run Time	4.12 hrs.
<sup>*</sup> This volume does not include 8 m <sup>3</sup> (11 yd <sup>3</sup> ) of material that was reprocessed.	

### **Area C Soils (Windblown Radionuclide Deposition)**

Area C soils were excavated using a grader and a bulldozer to windrow the top 7.6 cm to 10.2 cm (3 to 4 in.) of soil. The bulldozer was used when the soils became too muddy for using the grader. The soil windrows were picked up using a front-end loader, and loaded into dump trucks for stockpiling inside the SGS exclusion zone. After the excavated soil was removed from the area, the GPRS surveyed the area. The results of the initial and second survey show that approximately 50% of the remaining soils are below the 23 pCi/g action level. The remainder of the area soil exceeds 23 pCi/g, and would require further excavation. Table 5 summarizes the two days of routine soil processing for Area C soils.

**Table 5. ARA-23 Area C soil summary.**

Estimated Soil Stockpiled	679 m <sup>3</sup> (888 yd <sup>3</sup> )
Total Soil Processed	74 m <sup>3</sup> (97 yd <sup>3</sup> )
Estimated Oversized Material	25 m <sup>3</sup> (33 yd <sup>3</sup> ) (25.5%)
Total Soil Diverted	74 m <sup>3</sup> (97 yd <sup>3</sup> )
Total Activity Diverted	3.20E+09 pCi (53.4 pCi/g, Average concentration)
Total Activity Not Diverted	0.0 pCi
Clean-up Efficiency	0%
Actual Run Time	2.98 hrs.

The poor separation efficiency observed with the Area C soils led to the early shutdown of routine soil processing. This area was thought to be windblown, and the contaminant deposition heterogeneous in nature, and there was not an obvious explanation for the poor separation efficiency.

### **SGS Performance Tests Results**

At this point the processing was stopped and the parties involved agreed to determine why poor results were being achieved. The result of this action was a series of performance tests to evaluate the proper operation of the SGS, and determine the reason(s) for the poor separation efficiency of the ARA-23 soils.

### **Set-Point Test**

The set-point test was conducted on day 5 of soil processing. A total of 35 m<sup>3</sup> (46 yd<sup>3</sup>) of stockpiled soils from ARA-23 Area C were used for the set-point test. The set-point of the SGS was varied from 150 pCi/g to 23 pCi/g to determine if there was a concentration at which the SGS would sort the windblown contaminated soils. Table 6 summarizes the results of the Set-Point test. The results of the set-point test show that the windblown soils can be sorted if higher set-points are used. The most efficient sorting for a given set-point occurs using a MPF of 1 as opposed to using a MPF of 3.

**Table 6. Set-Point Test Results for Cs-137 Contaminated Soils.**

SGS Set-Point	Multiple Particle Factor	Observed Clean-up Efficiency
Total Soil Processed – 35 m <sup>3</sup> (46 yd <sup>3</sup> )		
150 pCi/g	(MPF=3)	90%
110 pCi/g	(MPF=3)	31%
80 pCi/g	(MPF=3)	9%
80 pCi/g	(MPF=2)	53%
80 pCi/g	(MPF=1)	60%
70 pCi/g	(MPF=3)	0%
70 pCi/g	(MPF=1)	11%
60 pCi/g	(MPF=3)	0%
50 pCi/g	(MPF=3)	0%

### **Shine Test**

The shine test was conducted on June 16, 1999, after the set-point test was run to evaluate the separation efficiency of the SGS on the soils with the higher activity particles removed. The shine test utilized Area C soils from the below criteria pile generated during the set-point test. These soils were assumed to have had the relatively hot particles removed during the Set-Point test, and should not contain soils with concentrations exceeding 70 pCi/g. A total of 9 m<sup>3</sup> (12 yd<sup>3</sup>) of soil were reprocessed during the shine test. Two different set-points were used during the shine test to fully evaluate the separation efficiency. The set-points used were 40 pCi/g and 23 pCi/g. Additionally, the SGS was operated with MPFs of 1 and 3 at each set-point. Table 7 shows the results of the shine test.

**Table 7. Shine Test Results for Cs-137 Contaminated Soils.**

SGS Set-Point	Multiple Particle Factor	Observed Clean-up Efficiency
Total Soil Processed – 9 m <sup>3</sup> (12 yd <sup>3</sup> )		
40 pCi/g	(MPF=3)	0%
40 pCi/g	(MPF=1)	1%
23 pCi/g	(MPF=3)	4%
23 pCi/g	(MPF=1)	0%

The results show that removal of the higher activity (i.e., >50 pCi/g) soils from the soil stream had little or no effect in increasing the SGS separation efficiency at the low set-point levels. One conclusion that could be drawn from the results of this test and the set-point test is that the levels of contamination in the windblown soils exceed 60 pCi/g. The average Cs-137 concentration in the soils prior to excavation is 73.4 pCi/g. It can be concluded that the Cs-137 is widely, and relatively homogeneously, distributed in the soils.

#### **Primary Cut Of Soils—Direct Haul Test**

The primary cut of soils from Area C were windrowed and direct hauled, by front end loaders, to the SGS unit for processing to evaluate the separation efficiency, at 23 pCi/g, of soils from 0 to 7.6 cm (0 to 3 in.). A total of 7 m<sup>3</sup> (10 yd<sup>3</sup>) of soil were processed for this test. The results of the primary cut test are presented in Table 8.

**Table 8. Primary Cut (direct haul) Test Results for Cs-137 Contaminated Soils.**

SGS Set-Point	Multiple Particle Factor	Observed Clean-up Efficiency
Total Soil Processed – 7 m <sup>3</sup> (10 yd <sup>3</sup> )		
23 pCi/g	(MPF=3)	15.7%

The Primary Cut test shows that some separation can be achieved at the 23 pCi/g set-point; however, it was insufficient to warrant further excavation or soil processing. The results of the two direct haul tests show that windrowing and direct hauling the soils to the SGS keeps the degree of contaminant homogeneity at a minimum, when compared to 0% separation efficiency for soils that have been windrowed, stockpiled, and then processed.

## **Second Cut of Soils—Direct Haul Test**

The second cut of soils from Area C were windrowed and direct hauled, by front end loaders, to the SGS unit for processing to evaluate the separation efficiency, at 23 pCi/g, of soils from 7.6 to 15.2 cm (3 to 6 in.) below land surface. A total of 12 m<sup>3</sup> (16 yd<sup>3</sup>) of soil were processed for this test. The MPF was varied from 1 to 3 during the test to further evaluate the separation efficiency of the SGS. The results of the second cut test are presented in Table 9. These results show that some separation is possible at 23 pCi/g when sorting with an MPF of 1; however, a majority of the soils (approximately 80%) exceed the 23 pCi/g action level, inferring that more soil may need to be removed to remediate the site.

**Table 9. Second Cut (direct haul) Test Results for Cs-137 Contaminated Soils.**

SGS Set-Point	Multiple Particle Factor	Observed Clean-up Efficiency
Total Soil Processed – 12 m <sup>3</sup> (16 yd <sup>3</sup> )		
23 pCi/g	(MPF=3)	0%
23 pCi/g	(MPF=1)	21.3%

## **Reprocessing of ARA-23 Area C Soils at 2.5 cm Soil Depth**

Soils from ARA-23 Area C were re-processed with the SGS, using a 2.5 cm (1 in.) screed gate height to evaluate the separation efficiency with less material and less activity on the belt. A total of 17 m<sup>3</sup> (23 yd<sup>3</sup>) were re-processed at a 2.5 cm (1 in.) layer on the belt. Operating the SGS with 2.5 cm (1 in.) of material precluded the use of unprocessed material due to material handling problems. The soil was reprocessed at set-points of 23 and 110 pCi/g, using MPF of 1 and 3 for each set point. The results of the 2.5 cm (1 in.) test are presented in Table 10.

**Table 10. 2.5 cm (1 in.) Test Results**

SGS Set-Point	Multiple Particle Factor	Observed Clean-up Efficiency
Total Soil Processed – 17 m <sup>3</sup> (23 yd <sup>3</sup> )		
110 pCi/g	(MPF=3)	99.7%
110 pCi/g	(MPF=1)	97.9%
23 pCi/g	(MPF=3)	3.0%
23 pCi/g	(MPF=1)	15.2%

The results of this test show that separation efficiency is high at the 110 pCi/g set-point, with the MPF appearing to have little influence on the sorting efficiency. In contrast, the sorting efficiency at the 23 pCi/g set-point was relatively low, with the MPF having a modest affect. The sorting efficiency possibly could have been slightly higher if the material had been handled fewer times prior to sorting.

## **Disposition of Treatability Study Soils and Site Closure**

The stockpiled soils, processed soils and oversized materials were returned to their respective areas of contamination, and sprayed with surfactant to mitigate the spread of airborne radioactivity. Additionally, disturbed areas were backfilled where required, and will be seeded as per the treatability study work plan (INEEL 1999a). The SGS test site was surveyed by BBWI radiological control, all project specific barriers were removed, and original boundaries for contamination areas reestablished.

## 6. SEGMENTED GATE SYSTEM COSTS

### **CONTRACTING METHOD**

Sandia National Laboratories, for the ASTD program, contracted the SGS on a per cubic yard rate for 1,000 cubic yards, with separate line items for mobilization, demobilization and final report costs. Total invoiced cost for this project was \$205,800.

### **COST BREAKDOWN**

Pre-deployment activities included transportation, lodging and personnel costs plus G&A for planning meetings and site visits at the INEEL. Mobilization costs included trucking costs to transport the SGS from Los Alamos, New Mexico to the INEEL, costs for transportation of the crew, at estimated cost plus G&A, to the INEEL site. Demobilization charges included trucking charges for the SGS from the INEEL to Albuquerque, New Mexico.

The per cubic yard operational costs included crew wages and per diem. Operational days included equipment unloading, assembly and calibration, operation during soil processing, decontamination, disassembly and loading of the equipment for shipment to the next job site. For the ASTD program, trucking charges for transportation to the next site were considered part of the mobilization charges for the next client. In cases where the SGS is not scheduled for another project, as was the case for the INEEL deployment, trucking charges would be considered part of the demobilization.

**Table 11. SGS Cost Breakdown**

<b>Cost element</b>	<b>Description</b>	<b>Subtotals</b>
Task 1	Pre-deployment activities	\$17,000
Task 2	Mobilization	\$69,000
Task 3	Processing	\$77,000
Task 4	Demobilization	\$39,000
Task 5	Final report	\$3,800
<b>TOTAL</b>		<b>\$205,800</b>

## SGS Treatability Study – INEEL Incurred Costs

There were substantial costs incurred by INEEL in preparing for, supporting and in wrapping up the SGS deployment and demobilization. Those costs are listed in Table 12.

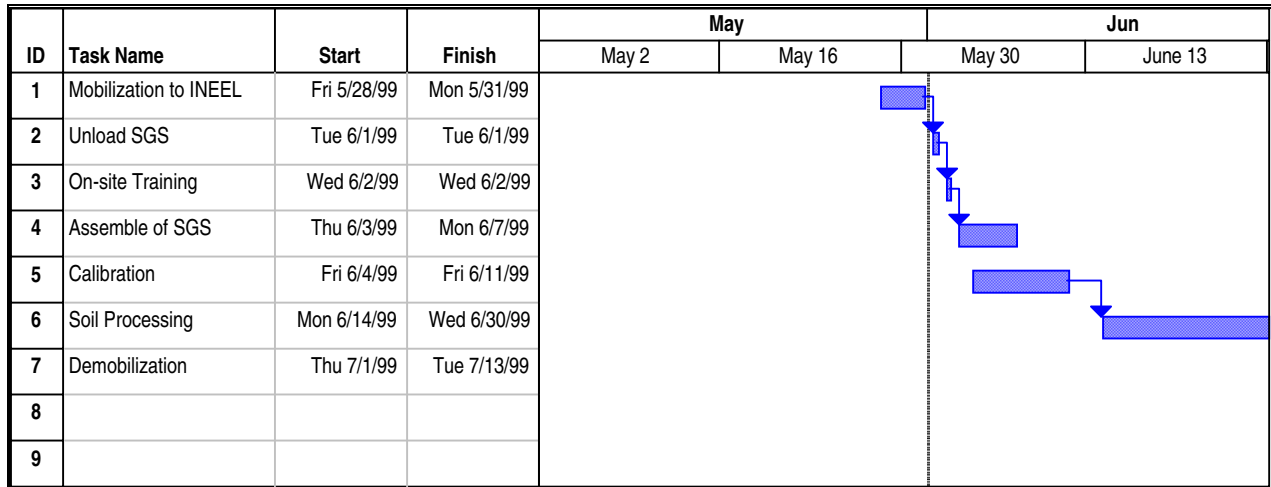
**Table 12. INEEL Incurred Costs**

<b>FY 1998</b>	<b>EM40 Dollars</b>	<b>EM50 Dollars</b>
Pre-planning Documentation and Project Management		26,600
Total		26,600
<b>FY 1999</b>	<b>EM40 Dollars</b>	<b>EM50 Dollars</b>
Pre-planning Documentation and Project Management	8,700	12,100
Waste Management and SWPP Plans	14,800	
Hazards Analysis	8,000	
NEPA Documentation	2,600	
Hazardous Waste Determinations	10,000	
Work Control	72,400	
Prepare Stage I RFP and Subcontract Procurement	12,400	
Start-up Project Management	22,600	
Sample Management Office Support	6,400	
Sampling Analysis		7,900
Mobilization and Setup		30,700
Excavation and Stockpiling		51,000
SCS Operations		20,700
Demobilization and Decontamination		20,700
Waste Dispositioning		2,200
Project Management		29,900
Final Report		7,700
<b>Totals</b>	<b>157,900</b>	<b>209,500</b>

Note: There will be additional charges for reseeded the excavated and disturbed areas and additional charges for completing the final report. It is estimated these cost will be less than \$25,000.

## 7. SCHEDULE

Figure 4 shows the tasks and schedule associated with the SGS project at the INEEL ARA-23. Two calibration intervals were required, cesium-137 and strontium-90. The schedule was completed early since only 442 cubic yards of soil was processed. The INEEL personnel requested demobilization be completed prior to the 4<sup>th</sup> of July holiday.



**Figure 4. SGS Tasks and Schedule at INEEL ARA-23**

## 8. REGULATORY/ INSTITUTIONAL ISSUES

A Consent Order and Compliance Agreement (COCA) was entered into between U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA) pursuant to the Resource Conservation and Recovery Act (RCRA) Section 3008(h) in August 1987. The COCA required DOE to conduct an initial assessment and screening of all solid waste and/or hazardous waste disposal units at the INEEL, and establish a process for conducting any necessary corrective actions.

On July 14, 1989, the INEEL was proposed for listing on the National Priorities List (NPL) (54 Federal Register [FR] 29820). The EPA proposed the listing under the authorities granted to EPA by CERCLA as amended by the Superfund Amendments and Reauthorization Act of 1986. The INEEL was listed on the NPL on November 21, 1989 (54 FR 44184). DOE, EPA, and the Idaho Department of Health and Welfare entered into the Federal Facility Agreement and Consent Order (FFA/CO) on December 9, 1991 as a result of the INEEL's listing on the NPL. Under terms of the FFA/CO, the INEEL was divided into 10 waste area groups (WAGs). The proposed work addressed under this treatability study was located in WAGs 3, 5, and 6. Under terms of the FFA/CO, the SGS treatability study is a CERCLA action conducted per the requirements set forth in the *Guide for Conducting Treatability Studies Under CERCLA-Final* (EPA 1992) under Operable Unit (OU) 5-12. Of the eight sites considered for inclusion in the treatability study, ARA-23 soils were the only soils used in the treatability study.

ARA-23 was included under terms of the OU 5-12 Record of Decision (ROD) scheduled to be signed in December 1999 in accordance with the FFA/CO. The OU 5-12 Proposed Plan was released for public comment on May 10, 1999. The proposed plan informed the public that the segmented gate system technology would be evaluated in the ROD where results of the treatability study would be incorporated.

## 9. OBSERVATIONS AND LESSONS LEARNED

### *Cost Observations and Lessons Learned*

The internal costs of deploying the SGS technology are greater than the external costs. Careful forecasting is required to identify the total costs involved prior to deployment.

### *Performance Observations and Lessons Learned*

A lessons learned meeting was held on June 29, 1999, with participation from the SGS Treatability Study project management, Radiological Control organization, Environment Safety and Health, Thermo NUtech, and equipment operators. The primary objective of the meeting was to allow personnel from all aspects of the project to provide input. This lessons learned meeting was also intended to provide information/suggestions that will help in preparing contract documents to be used during the actual remediation.

### *Planning*

Start early. This project required almost 4 months planning for the work, and the amount of paperwork required at the INEEL was significantly more than any of the other sites where the SGS was deployed. Involve all of the stakeholders early in the process. The SGS project team should have taken an equipment operator and representatives from safety and radiological controls to see the machine in operation at Los Alamos National Laboratory. It was thought that the same thing could be accomplished by showing videos of the equipment in operation, but it was not as effective. Thermo NUtech was impressed that all work control documentation and preliminary site work was completed prior to their arrival on Site. The INEEL setup of the equipment and the control zone provided excellent viewing opportunities for non-project personnel who did not have to have all of the required training.

The use of Thermo NUtech's Standard Operating Procedures worked very well and all future sites should be encouraged to use them without reinventing the wheel. A readiness assessment checklist was developed that helped focus on tasks that must be completed prior to SGS deployment.

### *Excavation*

A recommendation was made to kill the vegetation prior to excavation. The clumps of grass and the root zone made the 7.6-cm (3-in.) excavation very difficult. Additionally, the clumps of vegetation caused difficulties in keeping the SGS screen plant full and created obstructions in the SGS screen plant. This required extra efforts on TNU's part to keep a consistent stream of soil on the SGS conveyor. As a result of these difficulties, the oversized material (material unable to be processed with the SGS) comprised approximately 25.5% of the total stockpiled material. Another recommendation was to use an all wheel drive motor grader for windrowing the soils. Windrowing worked well for minimizing the depth of excavation and the amount of material removed, and maintaining a consistent excavation depth with varying terrain. However, windrowing may have increased the degree of homogenization of the contamination in the soil. Rain and mud made it difficult to minimize excavation depth, and in some places it precluded the use of the motor grader. In these instances a bulldozer was used; however, it was not the preferred equipment because contamination may have been spread during the excavation. Some thought should be given to future contracts so soil handling should be performed under optimal weather conditions.

### *Dust Control/Soil Moisture*

Conducting the excavation in the spring significantly reduced the amount of dust generated during excavation and stockpiling, but the excess soil moisture caused difficulties when windrowing, hauling, and loading material into the SGS. The soil moisture also caused difficulties in processing. Dust control was not a problem because the excavation was performed in the spring. Radiological control personnel noted that the visible dust still probably wasn't a problem at ARA-23 because the site is so large that any particles would not be carried by the wind beyond the boundary of the existing area of contamination. Watering stockpiles and excavated areas twice a day worked well to control fugitive dust.

A recommendation was made to water stockpiles and areas to be excavated the night before for best results. The best dust control was achieved by keeping the stockpiles wet, as opposed to misting or watering the soils when loading with the front-end loader.

### **Segmented Gate System Equipment**

Fix the remote control for lifting the grizzly (top screen on the hopper). Current configuration did not work reliably or consistently. An enhancement to the equipment would be to install a shaker on the grizzly to help process the oversized material. During set-up, the use of a forklift for slinging equipment is not recommended. A cherry-picker could have been used in place of the fork lift for moving equipment. The loader bucket width\* should be equal to, or slightly narrower than the width of the SGS hopper. A wider hopper (greater than 2.4 m [8 ft]) on the SGS unit would have been preferred. The use of side-boards or a wind shield on the hopper may allow the equipment to operate in dustier conditions. Always have a qualified equipment operator operating the heavy equipment.

\* **Table 1**, page 5: **Ancillary Equipment** specifies: "...loader with 2 to 5 yard bucket no wider than 8.5'..."

### **Radiological Control (RADCON)**

INEEL RADCON did an excellent job keeping the personal protective equipment (PPE) to a minimum by monitoring, and using good practical knowledge of the nature of the contamination.

A suggestion was made to obtain a waiver to DOE Order 5400.5 to allow wet decontamination\* of equipment without containment, when in an existing contaminated area. Thermo NUtech is to be complimented on the design of the equipment from a RADCON inspection/survey standpoint, simplifying the tasks required to survey and release the equipment.

\* Dry decontamination has repeatedly proven effective for unrestricted release of the SGS

### **Safety**

The INEEL model Health and Safety Plan (HASP) did not lend itself well to the project specific requirements and rather than force fit the project into the HASP format, the HASP format should have been used only where applicable. There were no near-misses or accidents due to the great safety awareness of all workers and the establishment of the equipment development area (INEEL 1999b).

### **Optimum Equipment Configuration for Large Scale Excavation**

A better method of tarping and sealing the beds of trucks is desirable. Automated covers like those used on potato hauling trucks were recommended. The use of larger dump trucks was recommended to help increase hauling efficiency. If the work is performed in-house it would be better to lease equipment rather than compete with other interests for government furnished equipment. Previously contaminated, government furnished equipment should be supplied for those jobs where the equipment can not be decontaminated, such as the use of the bulldozer in muddy conditions. The motor grader used for windrowing material worked better than the dozer because less contamination was tracked, and a more consistent excavation depth was maintained. It was recommended that the largest grader available be used due to the rocks and vegetation.

### **Teamwork**

The team commented that they never had to wait for decisions because decision making responsibilities were delegated to the field personnel. Preparation and planning for all the field activities allowed personnel to perform their tasks.

### **Site Characterization Prior to Future SGS Deployment**

Sample locations should be selected that transect the area of contamination. In the case of this treatability study it was evident that there were too many hot-particles above the action limit for the SGS to effectively segregate the material. Future deployments should attempt to determine a particle distribution based on radiological activity. INEEL CERCLA sampling calls for composite sampling from 0 to 15.2 cm (0 to 6 in.). Since the contamination was believed to be contained in the top 5.1 to 7.6 cm (2 to 3 in.), the analytical samples may have ended up being diluted. The sample depth selected should match the depth of contamination, if possible. Characterization data and site assessment should lead to an estimated volume reduction for the proposed site prior to SGS deployment.

### **Recommendations for the Main Soil Haul**

A recommendation was made to dedicate a haul road from ARA directly to the ICDF, which would alleviate congestion on the main roads and reduce the haul distance. Larger trucks would improve the haul efficiency to the ICDF. A quick truck tarping system and bed seal needs to be developed for the trucks that will be used for hauling. It was suggested that the type of tarp system used on potato haulers worked the best on previous soil removal actions. Depending on the final job configuration, it may be advantageous to have a loading ramp set up where a dozer would push the material to a loader.

Develop incentives for the contractor to minimize the depth of excavation since it was demonstrated that 7.6 cm (3 in.) of soil could be selectively excavated without significant cross-contamination. The post-excavation GPRS surveys show that most of the contamination was removed with the primary cut.

### **Other Project Successes**

The SGS assays matched the data collected by the GPRS very closely, which validates the use of the GPRS for gamma mapping, providing Cs-137 is the only gamma-ray emitting contaminant present.

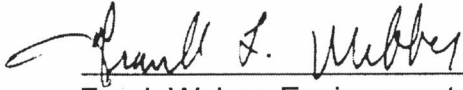
Based on the sampling performed during the study, the vegetation may not have to be treated as being radiologically contaminated, representing a potential \$163,000 cost savings.

## 10. REFERENCES

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2. *Guide to Documenting Cost and Performance for Remediation Projects*, Member Agencies of the Federal Remediation Technologies Roundtable, March 1995, EPA-542-B-95-002. (download at <http://clu-in.com/pubitech.htm>)
3. *HTRW Remedial Action Work Breakdown Structure*, Hazardous, Toxic, Radioactive Waste Interagency Cost Engineering Group, February 1996. (downloadable at [http://globe.lmi.org/lmi\\_hcas/wbs.htm](http://globe.lmi.org/lmi_hcas/wbs.htm))
4. *Avoidable Waste Management Costs*, Idaho National Engineering and Environmental Laboratory, January 1995.
5. *Treatability Study Work Plan for the Segmented Gate System Technology Deployment*, INEEL/EXT-98-01097, April 1999
6. *Summary Report for the Segmented Gate System Treatability Study*, INEEL/Ext-99-00733, Revision 0' October, 1999

## 11. Validation

**“This analysis accurately reflects the performance and costs of the deployment.”**



Frank Weber, Environmental Restoration Project Leader  
Waste Area Group - 5  
Idaho National Engineering and Environmental Laboratory



Ray Patteson, Technical Coordinator  
Accelerated Site Technology Deployment Program  
Sandia National Laboratories